



United States Government Accountability Office  
Washington, DC 20548

March 3, 2011

The Honorable Charles Bolden  
Administrator  
National Aeronautics and Space Administration  
300 E Street, SW  
Washington, DC 20024-3210

Subject: *Additional Cost Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects*

Dear Administrator Bolden:

Today, GAO published its third annual assessment of selected large-scale NASA projects.<sup>1</sup> During this assessment we identified several issues that merit your management attention.

The federal government faces real fiscal limitations and will have to make difficult choices about upcoming priorities. This reality makes it more important than ever that NASA manage its programs and projects as efficiently and effectively as possible and within a budget that over recent years has remained relatively constant. It will also require that NASA make tough decisions about which projects to fund among core missions in science, aeronautics, and human space flight and exploration. Our work over the past three years has shown that NASA's major projects are frequently approved without evidence of a sound business case—ensuring a match between requirements and resources—and, therefore, cost more and take longer to develop than planned. Our March 2011 assessment found that 13 NASA projects that established baselines prior to fiscal year 2009 had experienced an average cost growth of almost 55 percent, with a combined increase in development costs of almost \$2.5 billion from their baselines established at their Confirmation Review.<sup>2</sup> While NASA has taken steps over recent years to help improve its acquisition management through several initiatives aimed at improving cost estimating and management oversight, the overall outcomes of these efforts will take time to become apparent. Based on the findings of our past three assessments, we are recommending that NASA (1) provide increased transparency into project costs to the Congress to conduct oversight and ensure earlier accountability and (2) develop a common set of measurable and proven criteria to assess the design stability of projects before proceeding into later phases of development.

<sup>1</sup> GAO, *NASA: Assessments of Selected Large-Scale Projects*, [GAO-11-239SP](#) (Washington, D.C.: Mar. 3, 2011).

<sup>2</sup> The confirmation review is the point at which cost and schedule baselines are established and approved for the project. Project progress is measured against these baselines.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>03 MAR 2011</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2011 to 00-00-2011</b>	
4. TITLE AND SUBTITLE <b>Additional Cost Transparency And Design Criteria Needed For National Aeronautics And Space Administration (NASA) Projects</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>United States Government Accountability Office, Washington, DC, 20548</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>13</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## Lack of Transparency Into Early Project Development Costs

As we have reported, NASA does not provide enough transparency into costs during early project development to provide the Congress with sufficient information to conduct oversight and ensure earlier accountability.<sup>3</sup> While there is a need to allow projects a period of time for discovery and to pursue different concepts, projects can spend significant sums of time and money before they enter implementation<sup>4</sup> and are held accountable to a formal baseline. For example, authorized in 2005 and 2006 respectively, the Ares and Orion projects<sup>5</sup> have spent over \$9 billion combined, but neither has reached implementation. Furthermore, the James Webb Space Telescope was authorized in 1999, reached implementation in 2008, and spent nearly \$2 billion during those 9 years. The Senate Committee on Commerce, Science, and Transportation recently asked GAO to testify on how NASA can improve its overall transparency and accountability.

Currently, NASA does not provide to the Congress cost and schedule information for projects in the early, critical phases of development and makes this information public only after the projects have been formally approved to enter implementation. Projects establish preliminary cost estimates in the formulation phase; these estimates, however, are for planning purposes only as they enable NASA decision-makers to better manage the overall portfolio of projects. NASA does not report deviations from these early estimates to the Congress. Although progress is not measured or reported externally against early planning baselines, cost growth and schedule delays can and do occur during the formulation phase. NASA's internal analysis of past projects indicates that there is an average of 14 percent growth in the development cost estimates during the formulation phase. Additionally, NASA does not report information on the funding that has been authorized to date for the projects in formulation, as it does in its annual budget submission for projects in implementation. Additional insight into costs would provide critical information to help match project requirements to resources and could better enable the Congress to make more informed decisions when approving the projects through the annual appropriations process. Our prior reports have shown that early insight into project progress can put decision-makers in a better position to ensure projects have the resources necessary for success.

## Lack of Design Metric May Contribute to Project Cost Growth

During the course of our past three reviews of large-scale NASA projects and other work examining NASA's acquisition management,<sup>6</sup> we found that NASA does not use a common,

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<sup>3</sup> GAO, *NASA: Issues Implementing the NASA Authorization Act of 2010*, [GAO-11-216T](#) (Washington, D.C.: Dec. 1, 2010); [GAO-11-239SP](#).

<sup>4</sup> There are two phases in NASA's project life cycle—the formulation phase and the implementation phase. In the formulation phase, the project defines requirements—what the project is being designed to do—matures technology, establishes a schedule, estimates costs, and produces a plan for implementation. In the implementation phase, the project carries out these plans, performing final design and fabrication as well as testing components and system assembly, integrating these components and testing how they work together, and launching the project. This phase also includes the period from project launch through mission completion.

<sup>5</sup> As part of the Constellation Program, the Ares I Crew Launch Vehicle was designed to carry the Orion Crew Exploration Vehicle into low-Earth orbit for missions to the International Space Station and the Moon.

<sup>6</sup> GAO, *NASA: Implementing a Knowledge-Based Acquisition Framework Could Lead to Better Investment Decisions and Project Outcomes*, [GAO-06-218](#) (Washington, D.C.: Dec. 21, 2005); GAO, *NASA: Assessments of Selected Large-Scale Projects*, [GAO-09-306SP](#) (Washington, D.C.: Mar. 2, 2009); GAO, *NASA: Assessments of Selected Large-Scale Projects*, [GAO-10-227SP](#) (Washington, D.C.: Feb. 1, 2010); [GAO-11-239SP](#); and [GAO-11-216T](#).

proven metric to assess design stability before allowing programs to move from the design phase to the test and integration phase<sup>7</sup> of the development process. NASA's acquisition policy does not specify a metric by which a project's design stability is measured at the critical design review.<sup>8</sup> Guidance in NASA's *Systems Engineering Handbook*, however, mirrors an accepted best practice<sup>9</sup> that at least 90 percent of engineering drawings should be releasable by the critical design review, although projects are not required to follow this guidance.<sup>10</sup> We have found that if design stability is not achieved at the critical design review, but product development continues, costly re-designs to address changes to project requirements and unforeseen challenges can occur. As shown in figure 1, nearly all of the projects we reviewed over the last three years held their critical design review without 90 percent of engineering drawings being releasable—failing to meet NASA's *Systems Engineering Handbook* guidance and our best practices criteria for design stability. The only two projects in our 2011 review that met the design criteria—Orbiting Carbon Observatory-2 and Tracking and Data Relay Satellite Replenishment—to date have experienced no cost growth; however, these projects are based heavily on previous designs. Ten projects did not meet the design criteria and, of those, nine had experienced development cost growth since their baseline.

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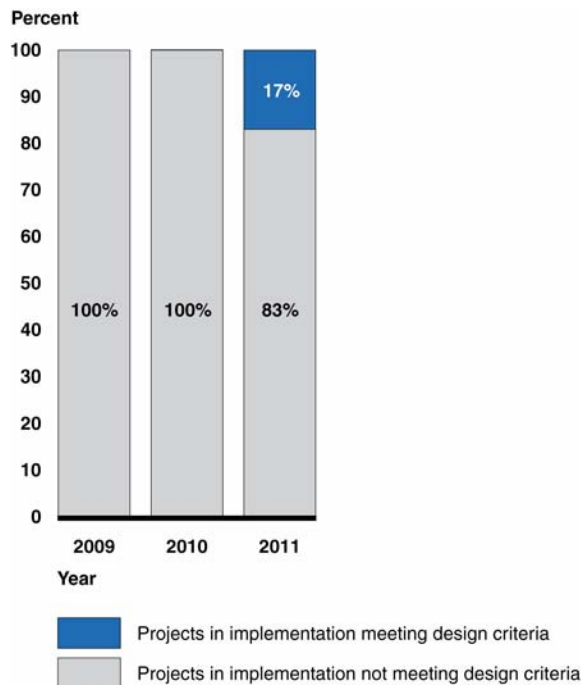
<sup>7</sup> During the design phase, the project completes its preliminary design and technology development and begins fabrication of test and flight article components, assemblies, and subsystems. In the test and integration phase, the project initiates system assembly, integration and test in preparation for flight.

<sup>8</sup> According to NASA Interim Directive for NASA Procedural Requirements 7120.5D, Table 2-7 (Sept. 22, 2009), the critical design review demonstrates that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and test, and that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet mission performance requirements within the identified cost and schedule constraints. Progress against management plans, budget, and schedule, as well as risk assessments, are presented.

<sup>9</sup> GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, [GAO-02-701](#) (Washington, D.C.: July 15, 2002).

<sup>10</sup> Engineering drawings are considered to be a good measure of the demonstrated stability of a product's design because the drawings represent the language used by engineers to communicate to the manufacturers the details of a new product design—what it looks like, how its components interface, how it functions, how to build it, and what critical materials and processes are required to fabricate and test it. Once the design of a product is finalized, the drawing is "releasable".

**Figure 1: 2009-2011 Trend of Design Criteria for Projects in Implementation**



Source: GAO analysis data provided by NASA.

Note: In our 2009, 2010, and 2011 assessments we reviewed 10, 9, and 12 projects, respectively, that were in implementation and had held their critical design review.

Some of the projects we reviewed in the past three years identified other activities that occurred prior to the critical design review as evidence of design stability. In addition to releasable engineering drawings, NASA relies on subject matter experts in the design review process and other methods to assess design stability. For example, a panel of experts within NASA provides an assessment of the technical and programmatic approach, risk posture, and progress against the project baseline at key decision points to be assured that the project has a stable design. Some projects rely on using engineering models and engineering test units to assess design stability. According to NASA's systems engineering policy, at the critical design review the project's design should be stable enough to support full scale-fabrication, assembly, integration, and test.<sup>11</sup> However, a recent study by the National Research Council<sup>12</sup> found that the critical design review milestone for many NASA missions may be held prematurely—driven by schedule rather than driven by design maturity. Furthermore, we found that the majority of the 12 projects in our March 2011 review<sup>13</sup> that had held their critical design review experienced increases in the number of engineering drawings that were expected after that review—an indication of an unstable design after the critical design review. This is particularly evident for the four projects that held their critical design reviews prior to fiscal year 2009—the projects that entered the test and integration phase in 2009 or

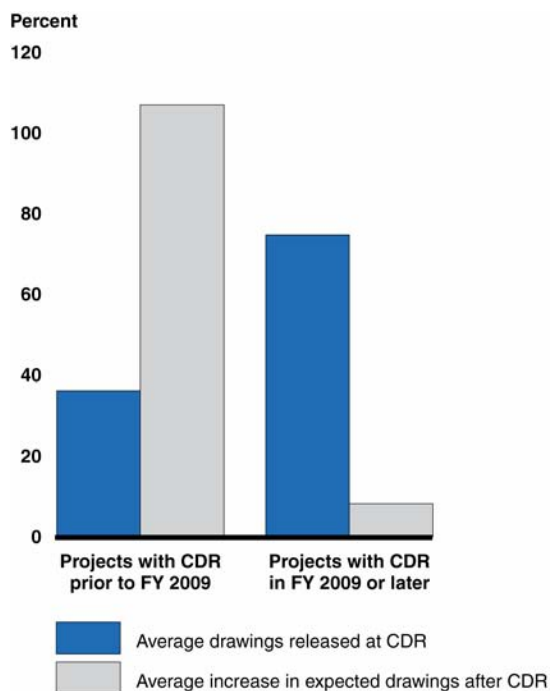
<sup>11</sup> NASA Procedural Requirement 7123.1A, *NASA Systems Engineering Processes and Requirements* Appendix G, paragraph G.8 (Mar. 26, 2007).

<sup>12</sup> *Controlling Cost Growth of NASA Earth and Space Science Missions*, National Research Council, The National Academies, Washington D.C. 2010.

<sup>13</sup> Sixteen projects in our 2011 review were in the implementation phase. Of those, twelve projects had held their critical design reviews and could provide information on the number of design drawings.

before and have more of a history to track variances.<sup>14</sup> As shown in figure 2 below, the four projects, on average, had a 107 percent increase in expected engineering drawings after the critical design review after having only 36 percent of drawings releasable at that review. The remaining eight projects that held their critical design review in fiscal year 2009 or later have not reported a large increase in expected drawings. All of these projects will enter or have entered the test and integration phase in 2010 or later. A National Research Council study states that approval of an immature design at the critical design review can cause problems during test and integration such as integration difficulties and late design changes. An increase in design drawings is one indication of late design changes.

**Figure 2: Comparison of Design Drawing Increase for Projects with Critical Design Review (CDR) prior to and since Fiscal Year 2009**



Source: GAO analysis of data provided by NASA.

Regardless of how stability is measured, consistent, proven, and quantitative measures employed at the critical design review—such as the percentage of engineering drawings—can provide evidence that the design is stable and will meet performance requirements. These measures can also be an indication to decision-makers that the requisite knowledge has been attained to allow the project to proceed in its development lifecycle and better enable them to assess the performance of individual projects against the overall portfolio of projects.

<sup>14</sup> We began tracking the percentage of drawing releasable as a measure of the design stability of selected large-scale NASA projects in our 2009 assessment. Since then, NASA provides drawing information on projects included in our yearly assessment on a semiannual basis.

## Conclusions

Over the past several years, our assessments have shown that NASA's major acquisitions have been marked by cost overruns and schedule delays. Given the multiple priorities that NASA must balance—coupled with the constraints that will continue to bind the government's fiscal resources for many years—ensuring that NASA is basing its acquisition decisions on correct, timely, and consistent information is critical. While NASA has undertaken several initiatives aimed at improving its acquisition management, the lack of transparency into the cost of projects in the early, critical phases of development leaves the Congress with incomplete knowledge to inform its oversight and ensure earlier accountability. While there is a need to allow projects a period of time for discovery and to pursue different concepts, particularly highly complex efforts, inadequate transparency into project progress for what sometimes amounts to 5 or more years can preclude effective oversight and accountability and make it even more difficult to stop projects that are not on track to meet the agency's goals with available resources. Finally, without a standard design metric to measure the projects' progress at crucial points in the development life cycle, NASA cannot be assured that its decisions will result in the best possible return on its investments.

## Recommendations for Executive Action

To provide increased transparency into project risks, we recommend that you

- Direct the Office of the Chief Financial Officer (OCFO) to provide more transparency into project costs in the early, critical phases of development so that the Congress has sufficient information to conduct oversight and ensure earlier accountability. Specifically, the OCFO should provide progress reports for NASA space flight programs and projects in formulation that include information on cumulative prior budget authority and current cost ranges in NASA's annual budget submission to the Congress to enhance the knowledge with which they base funding decisions for NASA.

To provide NASA decision-makers with a mechanism to consistently and accurately judge design stability, we recommend that you

- Direct the Office of the Chief Engineer to develop a common set of measurable and proven criteria, such as the percentage of releasable design drawings, to assess design stability and to allow decision-makers to make more informed, consistent determinations of approval for projects to proceed from the final design phase to the assembly, integration, and test phase of the development process and amend NASA's systems engineering policy, accordingly.

## Agency Comments and Our Evaluation

In written comments on a draft of this report, the Deputy Administrator of NASA partially concurred with our first recommendation and concurred with our second the recommendation. NASA's comments are reprinted in the Enclosure.

NASA partially concurred with our recommendation to provide more transparency into project costs in the early, critical phases of development in order to provide the Congress sufficient information to conduct oversight and ensure earlier accountability. While NASA agreed that clarity is needed into life-cycle cost range estimates, it stated that the estimates developed during formulation are not a baseline, and therefore not a basis for measurement of cost growth. Preliminary cost estimates are used by NASA to determine whether there is a good match between requirements and resources when designing a project. NASA stated that it currently provides these preliminary cost range estimates upon request, and is considering providing increased information for projects in early formulation in the annual budget submission to the Congress. NASA did not commit, however, to providing information to the Congress on the cumulative prior budget authority for projects in formulation, as we recommended. We understand that preliminary cost estimates are distinct from the baseline costs of the project and are not intended as a basis to measure cost growth. These early cost estimates do, however, provide the basis of the financial investment that the agency is committing the government to and should be transparent to Congressional decision-makers for their deliberation and decision-making. The lack of transparency into project progress early in development can preclude the ability of the Congress to conduct oversight and ensure accountability and make it even more difficult to stop projects that are not on track to meet the agency's goals with available resources. Similarly, given NASA's various accounting changes throughout the past decade, it is difficult if not impossible for the Congress and parties external to NASA to determine the cumulative budget authority or the investment to date that has been given to a particular project. Providing this type of budget information would allow Congressional decision-makers insight into the commitments to the project thus far to make informed decisions about their continued approval.

NASA concurred with our second recommendation that the agency develop a common set of measurable and proven criteria to assess design stability. NASA stated that the drawing release metric is a legacy standard developed prior to the use of computerized drawings, and hence does not take into account improvements due to the use of this technology. We acknowledge this point, but our analysis of NASA projects shows that those projects that have met or come close to meeting the best practices drawing release metric have fared better with regard to cost and schedule than those projects that did not come close to meeting the metric. NASA recognizes the need for metrics for greater insight into project formulation and development and stated that it is developing a common set of measurable and proven criteria to assess design maturity, which it will provide to GAO no later than March 31, 2011.

### Scope and Methodology

The majority of our findings in this correspondence were based on work completed as part of our 2011 *Assessments of Selected Large-Scale Projects*. In the assessment, we reviewed cost growth and design maturity of 21 projects, each with an estimated life-cycle cost of over \$250 million. We conducted interviews with project officials and examined the current phase of a project's development and how each project was advancing. NASA provided updated cost and schedule data as of February 2011 for 16 of the 21 projects. We reviewed and compared that data to previously established cost and schedule baselines. We assessed each project's cost and schedule and characterized growth in either as significant if it exceeded the

thresholds that trigger reporting to the Congress under the law.<sup>15</sup> We also reviewed NASA's February 2011 budget submission to the Congress and noted differences between cost information provided for projects in implementation versus cost information provided for projects in formulation. In addition, NASA provided cost and schedule information from previously reported projects that we used for historical analysis. Through a standardized data collection instrument, we gathered basic information about the projects as well as current and projected development activities for those projects, including information concerning the project's engineering design drawings. We used this data to assess design stability against GAO's established criteria for knowledge-based acquisitions and on other GAO work on system acquisitions. We reviewed and discussed NASA policies and in-house practices related to evaluating the design stability of each project. We took appropriate steps to address data reliability.

We conducted this performance audit in February 2011 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

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We are sending copies of this report to interested congressional committees. In addition, the report will be available at no charge on GAO's Web site at <http://www.gao.gov>. If you have any questions, please contact me at (202) 512-4841 or [chaplainc@gao.gov](mailto:chaplainc@gao.gov). Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this letter.

Key contributors to this report were Shelby S. Oakley, Assistant Director; Jessica M. Berkholtz; Richard A. Cederholm; Laura Greifner, Kristine R. Hassinger, and Roxanna T. Sun.



Cristina Chaplain

Director  
Acquisition and Sourcing Management

(120961)

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<sup>15</sup> NASA is required to report to Congress if development cost of a program is likely to exceed the baseline estimate by 15 percent or more, or if a milestone is likely to be delayed by 6 months or more. 42 U.S.C. § 16613(d).

Enclosure: Comments from the National Aeronautics and Space Administration

National Aeronautics and  
Space Administration  
**Office of the Administrator**  
Washington, DC 20546-0001



February 23, 2011

Ms. Christina Chaplain  
Director  
Acquisition and Sourcing Management  
United States Government Accountability Office  
Washington, DC 20548

Dear Ms. Chaplain:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review the Government Accountability Office (GAO) draft correspondence entitled "Additional Cost Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects" (GAO-11-364R). NASA values the continued open communications between NASA and the GAO team on the annual assessment of large-scale projects and appreciates the constructive comments arising as a result of this effort.

NASA agrees with the GAO's concern about managing programs and projects as efficiently and effectively as possible, especially within a budget that is likely to be constrained due to the fiscal limitations currently faced by all Federal Government agencies. Consequently, NASA remains dedicated to continuous improvement of acquisition management processes and performance. We are pleased that GAO recognizes NASA's ongoing efforts to mitigate acquisition management risk and lay a stronger foundation for reducing project cost and schedule growth. As was highlighted in the annual assessment, NASA implemented a Joint Cost and Schedule Confidence Level (JCL) policy in 2009 to increase the likelihood of project success at the specified funding level. Since institution of this policy, the average cost growth for NASA's large scale projects has remained below the 15 percent threshold which, if breached, requires special notification to Congress. NASA will continue to assess the effect of utilizing JCLs to manage project cost and schedule growth. With the completion and launch of three missions in 2011, NASA will have a better measure of the impact of our acquisition management improvement efforts over the last five years.

In the draft report, GAO makes two recommendations to the Administrator intended to increase transparency into project risks and to provide NASA decision makers with a mechanism to consistently and accurately judge design stability, specifically:

**Recommendation 1:** Direct the Office of the Chief Financial Officer (OCFO) to provide more transparency into project costs in the early, critical phases of development so that

the Congress has sufficient information to conduct oversight and ensure earlier accountability. Specifically, the OCFO should provide progress reports for NASA space flight programs and projects in formulation that include information on cumulative prior budget authority and current cost ranges in NASA's annual budget submission to the Congress to enhance the knowledge with which they base funding decisions for NASA.

**Management's Response:** Partially concur. NASA agrees with the need to provide clarity on life-cycle cost range estimates, but the estimates developed during formulation are not a baseline, and therefore not a basis for measurement of cost growth. As recognized by GAO, these estimates are used by NASA decision makers to manage the overall portfolio of projects. Furthermore, these preliminary estimates are used to help NASA determine whether there is a good match between requirements and resources given the project design trades at that point in time. The decision to approve a mission to proceed to development involves a complex balance between a mission's technical design, scientific and technical priorities, schedule, available resources within a portfolio of projects, and overall risk assessment of mission success given the requirements and constraints. Trades between all of these areas may or may not lead to growth in the cost estimate. When a project is approved to proceed to development, these trades are complete; NASA confirms that the requirements match the available resources, and commits to complete the project within the life-cycle cost estimate based on this match.

NASA currently provides preliminary cost range estimates, inclusive of prior year costs, for projects that have passed Key Decision Point B (KDP-B), upon request. For example, these ranges are published annually as part of the GAO's assessment of NASA's large-scale projects. NASA is also considering providing increased information for projects in early formulation in the annual budget submission.

**Recommendation 2:** Direct the Office of the Chief Engineer to develop a common set of measurable and proven criteria, such as the percentage of releasable design drawings, to assess design stability and to allow decision-makers to make more informed, consistent determinations of approval for projects to proceed from the final design phase to the assembly, integration, and test phase of the development process and amend NASA's systems engineering policy, accordingly.


**Management's Response:** Concur. NASA agrees that projects should have a stable design before starting assembly, integration, and test. Standing Review Boards (SRB) comprised of independent technical and programmatic experts are asked to assess design stability at Preliminary Design Review (PDR) and Critical Design Review (CDR) using a number of criteria that are outlined in NASA's system engineering and independent review policies. The drawing release metric referenced in NASA's *Systems Engineering Handbook* is a legacy standard developed prior to the use of computerized drawings and hence does not take into account improvements due to the use of this technology. For this reason, although NASA continues to use drawing release as one of many indicators, the Agency does not place as much emphasis on drawing release when considered

holistically along with other criteria to assess design stability. NASA does recognize the need for metrics for greater insight into project formulation and development. NASA concurs with GAO's recommendation to develop a common set of criteria to assess design stability. NASA is developing a common set of measurable and proven criteria to assess design maturity. The metrics will be provided to GAO no later than March 31, 2011.

NASA will continue to follow through with our new policies and management attention on cost and schedule growth and project management in the coming year. We are committed to continuous improvement in order to explore and utilize space in an affordable way for the benefit of the Nation. To this end, we look forward to continuing to work with the GAO to measure and improve our performance and management practices.

Thank you for the opportunity to comment on this draft report. If you have any questions or require additional information, please contact Katie Gallagher at (202) 358-2185.

Sincerely,



Lori B. Garver  
Deputy Administrator

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